Azimuthal anisotropy: the higher harmonics [1]

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Elliptic flow, v_2, is well studied at RHIC and is thought to reflect conditions from the early time of the collision. Recently, Kolb [2] reported that the magnitude and even the sign of v_4 are more sensitive than v_2 to initial conditions in the hydrodynamic calculations.

Experiment— The data come from the reaction Au + Au at $\sqrt{s_{NN}} = 200$ GeV. The STAR detector main time projection chamber (TPC) was used in the analysis of two million events.

Analysis— The difficulty is that the signal is small and the non-flow contribution to the two-particle azimuthal correlations can be larger than the correlations due to flow. To suppress the non-flow effects the current analysis uses the knowledge about the reaction plane derived from the large elliptic flow. We designate the results by $v_4\{EP_2\}$.

P_t-dependence— The results as a function of p_t are shown in Fig. 1 for minimum bias collisions (0 – 80% centrality) and $|\eta|<1.2$. Shown for v_4 are both the analysis relative to the second harmonic event plane, $v_4\{EP_2\}$, and the three-particle cumulant, $v_4\{3\}$. Both methods determine the sign of v_4 to be positive. The $v_6(p_t)$ values are consistent with zero. To test $v_2^{n/2}$ scaling we plot the dotted curves.

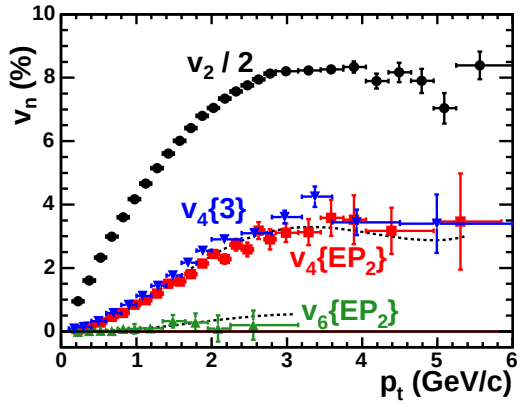

FIG. 1: The minimum bias values of v_2, v_4, and v_6 with respect to the second harmonic event plane as a function of p_t. The v_2 values have been divided by a factor of two to fit on scale. Also shown are the three particle cumulant values (triangles) for v_4 ($v_4\{3\}$). The dotted curves are 1.2 v_2^2 and 1.2 v_2^3.

Parton coalescence— Assuming a simple parton coalescence model, for mesons one gets [3]

$$v_4/v_2^2 \approx 1/4 + 1/2(v_4^q/(v_2^q)^2). \quad (1)$$

Since experimentally this ratio is 1.2, v_4^q must be greater than zero. If one assumes that the hadronic v_2^2 scaling results from partonic v_2^2 scaling [4], then

$$v_4^q = (v_2^q)^2 \quad (2)$$

and

$$v_4/v_2^2 = 1/4 + 1/2 = 3/4. \quad (3)$$

But this is still less than 1.2. Therefore either v_4^q is even greater than simple parton v_2^2 scaling would indicate, or the simple parton coalescence model is inadequate.

Centrality-dependence— Integrating over p_t weighted with the yield gives Fig. 2 which shows the centrality dependence of v_2, v_4, and v_6 with respect to the second harmonic event plane and also v_4 from three-particle cumulants ($v_4\{3\}$). The v_6 values are close to zero for all centralities. To again test the applicability of $v_2^{n/2}$ scaling we also plot the dotted histograms.

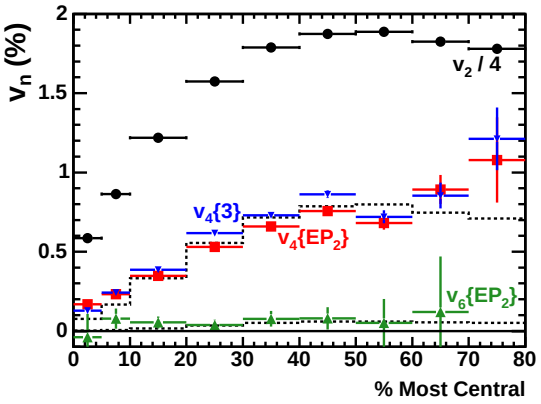

FIG. 2: The p_t- and η- integrated values of v_2, v_4, and v_6 as a function of centrality. The v_2 values have been divided by a factor of four to fit on scale. Also shown are the three particle cumulant values $v_4\{3\}$. The dotted histograms are 1.4 v_2^2 and 1.4 v_2^3.

Conclusions— We have measured v_4 as a function of p_t, and centrality. This is the first measurement of higher harmonics at RHIC. It is expected that these higher harmonics will be a sensitive test of the initial configuration of the system, since they provide a Fourier analysis of the shape in momentum space which can be related back to the initial shape in configuration space.

[1] J. Adams et al., Phys. Rev. Lett. **92**, 062301 (2004).
[2] P. Kolb, Phys. Rev. C **68**, 031902(R) (2003).
[3] P. Kolb, L.-W. Chen, V. Greco, , and C. Ko, Preprint *arXiv* nucl-th/0402049 (2004).
[4] L. Chen, C. Ko, and Z.-W. Lin, Preprint *arXiv* nucl-th/0312124 (2003).